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THE DEVELOPMENT OF AN INERT SIMULANT FOR HNS/TEFLON EXPLOSIVE

Wayne L. Elban

Naval Ordnance Laboratory
White Oak, Maryland

14 November 1972

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NAVAL ORDNANCE LABORATORY, WHITE OAK, SILVER SPRING, MARYLAND

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Prepared by:
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Approved by: A. B. DIETEMANN, Chief
Chemical Engineering Division
Chemistry Research Department
U. S. NAVAL ORDNANCE LABORATORY
White Oak, Maryland

 14 November 1972

The Development of an Inert Simulant for HNS/Teflon Explosive

(U) This report describes the development of an inert simulant for HNS/Teflon explosive required for hardware tests in connection with the Lunar Seismic Profile Experiment. This work was supported under NOL Task 998/NASA.

ROBERT WILLIAMSON II
Captain, USN
Commander

ALBERT LIGHTBODY
By direction

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TABLES

1. Introduction

A program was undertaken at the Naval Ordnance Laboratory to develop an inert simulant for the thermally stable, heat-resistant plastic-bonded explosive HNS/Teflon* (reference (1)). HNS/Teflon has been used by the National Aeronautics and Space Administration in the Apollo Lunar Surface Experimental Package (ALSEP) and consists of 90% HNS (2,2', 4,4', 6,6' - Hexanitrostilbene (reference (2))) and 10% Teflon binder. In this experiment the explosive is formed into a number of charges of differing yields and loaded in a grenade launcher which hurls the charges to various distances on the moon. The charges detonate on impact, creating seismic echoes that are recorded by seismometers placed on the moon's surface and transmitted to monitoring stations on earth. The purpose of this test program is to obtain knowledge about the structure of the lunar surface.

The material used in the ALSEP program was prepared by slurrying HNS with aqueous dispersed Teflon 30 (reference (3)), breaking the suspension with acetone and then allowing the material to settle. The resultant moulding powder was then filtered and dried, ready to be compacted and machined into explosive charges.

In another application HNS/Teflon is being used in a seismic refraction system scheduled to be carried aboard Apollo 17 as the Lunar Seismic Profiling Experiment (LSPE). This experiment utilizes seismic energy produced by detonating the explosive to acquire data on the physical properties of the surface of the moon. It was in connection with this work that the development of an inert simulant for HNS/Teflon was undertaken.

The testing and evaluation of explosive-loaded hardware for characteristics other than explosive sensitivity, output and performance are frequently conducted in an inert-loaded configuration. The use of explosive simulants simplifies certain phases of a hardware test program by greatly reducing safety requirements. Devices loaded with energetic materials make costly facilities and precautions necessary while an inert system may be tested without such limitations.

The properties that the explosive hardware designer may specify for a given simulant are many and varied. They include:

a. Density
b. Mechanical properties
c. Magnetic properties
d. Thermal conductivity and specific heat
e. Coefficient of thermal expansion
f. Resistance to temperature extremes
g. Machinability

*Teflon is a registered tradename of E. I. du Pont de Nemours and Company, Inc. for polytetrafluoroethylene.

As a practical matter only those properties desired for a particular application need to be simulated.

In this program most of the effort was directed toward formulating a simulant that closely matched the density, specific heat, and thermal conductivity of HNS/Teflon. It was also desired that the simulant be a pressed composition using a moulding powder having good processing and handling characteristics. It was also equally important that the moulding powder be homogeneous and easily compacted into billets having sufficient green strength to be readily machinable. Finally, finished simulant charges were to be subjected to temperature-vacuum cycling, making it necessary that the simulant successfully withstand 150°C without decomposing or subliming.

2. Early Development Work

2.1 Materials Selection: Teflon was chosen as the simulant binder because of its excellent thermal stability at 150°C. In addition it has been utilized successfully as a binder in the preparation of explosive charges for the ALSEP program. Based on this experience it was decided that aqueous dispersed Teflon 30 would be used in formulating inert compositions. Several product bulletins (references (3) and (4)) describe Teflon 30 giving typical properties as well as the preparation and moulding of solids-filled compositions.

Since HNS is an organic compound, a search (references (5) and (6)) was conducted to find organic materials suitable as inert filler ingredients. A list of potential candidates capable of meeting the 150°C temperature is given in Table 1. These materials were further screened on the basis of density, solubility in water, toxicity and cost. From this list melamine and terephthalic acid were thought to be most suitable. Oxamide was considered as a third possibility with high cost being the objection.

2.2 Processing Procedure: Before formulating simulants based on Teflon 30 it was necessary to determine the amount of solids in the emulsion. This was done by placing a known amount of emulsion in a tared container and evaporating the material to dryness in a 105°C oven. The container was then reweighed and the percent solids was calculated. Table 2 summarizes the results of this work. The average of three determinations, 63.55%, was used to calculate the amount of emulsion necessary to give the desired level of Teflon in the simulant formulations. In actual fact this technique for calculating the desired amount of Teflon is somewhat in error since the emulsion is stabilized with a wetting agent, typically 5.5 to 6.5% based on the weight of the resin (reference (3)), which is left behind on evaporating the emulsion.

Three simulant trials were made using Teflon 30 aqueous dispersion with melamine as the primary filler ingredient. Exact compositions are given in Table 3.

A typical small batch mixing procedure for making 100 gm of moulding powder is given as follows:

The filler material (62.7 gm of melamine) was placed in a 1000 ml beaker with 100 ml of distilled water and slurried for 5 minutes with an electric stirrer operating at 250 rpm. Teflon 30 emulsion (58.7 gm) was slowly added while stirring. After mixing for an additional five minutes, 200 ml of reagent grade acetone was added while stirring. Mixing was continued for 5 minutes and then stopped. A two phase solution resulted with a melamine-Teflon layer at the bottom. Additional acetone (10 ml) was added dropwise to determine whether the Teflon had completely precipitated. The solution was then filtered through a 15.5 cm Büchner funnel using #54 Balston paper; vacuum was continued for 30 minutes. The resulting material was a damp cake that was removed from the funnel and dried for 24 hours at 50°C.

2.3 Results and Discussion: Several problems arose in formulating Simulant Trial #1. The addition of acetone to the simulant slurry resulted in the formation of foam or flocculent that served to entrap Teflon. Also, it was difficult to control the size of the Teflon particles during precipitation. While most of the precipitate was extremely fine as desired, numerous particles were observed whose nominal diameter exceeded 2-3 mm. Inspection of the dried moulding powder revealed that it was tacky and not free-flowing. Instead, agglomerates as large as a centimeter in diameter were obtained and presented handling difficulties. It was impossible to visually determine the degree of homogeneity of the powder since all ingredients were white. Some of this material was hydraulically compacted at 1757.75 kg/cm^2 (25000 psi) in a 2.5 cm (one inch) diameter steel mould and had a pressed density of 1.69 gm/cm^3.

Based on handling experience with HNS/Teflon 30, it was felt that perhaps Trial #1 had too much Teflon. Simulant Trial #2 was made with about one-third as much Teflon and kaolin was added to obtain the desired density. The exact composition is given in Table 3. While not an organic compound, kaolin was used as a filler material because it met the criteria under which melamine was chosen and a sufficiently large quantity was available. The results were about the same as those experienced in Trial #1. The foaming persisted and there was only slight improvement in handling the moulding powder. A pellet was pressed having a density of 1.67 gm/cm^3.

Simulant Trial #3 consisted of adding 0.01 wt percent Dow Corning* Antifoam H-10 Emulsion (reference (7)) to Trial #2 in an attempt to alleviate the foaming problem. The antifoaming agent was added to 10 ml of distilled water and agitated with a spatula. This was then added to the simulant slurry just before the acetone was added to break the Teflon emulsion. Only a slight reduction in flocculent formation occurred. Additional antifoaming agent did not lessen the foaming condition. A pellet of Simulant Trial #3 had a

*Dow Corning is a registered tradename of the Dow Corning Corporation.

density of 1.71 gm/cm^3.

Simulants made with Teflon 30 emulsion had several shortcomings. Besides the foaming problem, the tacky texture and non free-flowing nature of the moulding powder presented handling difficulties. Also, compositions based on Teflon 30 emulsion required large volumes of acetone and water; this was considered impractical for processing large quantities of simulant.

3. Further Development Work Leading to the Selected Simulant Composition

3.1 Substitution of Powdered Teflon for Aqueous Dispersed Teflon: It was learned (reference (8)) that the problems encountered in preparing Teflon 30-based moulding powders were characteristic of the emulsion. In view of the inherent shortcomings in using Teflon 30 for solids-loaded systems, it was suggested that dry powdered Teflon 7C be substituted for the aqueous dispersed Teflon 30. Teflon 7C is a granular powdered moulding resin with an average particle size of 30 micron as determined by air sedimentation and an approximate bulk density of 250 gm/l. Of the Teflon TFE resin powders available for moulding, it has been Du Pont's experience that composites utilizing Teflon 7C have the highest green strength (reference (8)). The small particle size permits a good Teflon dispersion while the fibrous nature of the Teflon particles contributes to improved uniformity and physical properties of filled systems (references (8) and (9)).

The advantages in substituting Teflon 7C for Teflon 30 are derived primarily from being able to use processing techniques similar to those used in powder metals technology. Since filler materials are combined and dry blended with Teflon 7C, the foaming phenomena and, of course, the need for acetone and water are eliminated. In addition, the handling problems encountered with Teflon 30-based moulding powders would most likely be considerably reduced since Teflon 7C and the filler materials are free-flowing.

3.2 Experimental

3.2.1 Processing Procedure: There is considerable information (references (10), (11), (12) and (13)) available concerning the mixing of solid particles. A method for blending with Teflon 7C is also described and has been used successfully in making composites (reference (14)). For this work mixing was effected using a horizontal ball mill; ceramic balls were added to the mixing container to break up lumps.

The small scale dry blending procedure for preparing the remaining simulant trials is given below:

The required quantities of Teflon and filler materials were weighed and placed in a smooth-walled cylindrical drum. In an effort to insure thorough mixing, the contents filled a maximum one-third of the total volume of the drum. To avoid powder agglomeration a quantity of 2.0-2.5 cm diameter ceramic balls were placed inside the

drum. The exact number of balls used was determined by making the sum of the balls' diameters about one-half the drum height. Mixing was accomplished by rolling the drum on a horizontal ball mill at a rotational speed of 120 rpm for eight hours. The moulding powder was then dried at 50°C for 24 hours.

Seventeen simulant compositions were made using the procedure outlined above for batch sizes ranging from 50 to 500 **gm.** Due to the immediate unavailability of Teflon 7C and the urgency attached to this program, it was decided to begin formulating inert compositions using Teflon 5 (reference (15)) until Teflon 7C was obtained. Having an average particle size of 300 microns and an approximate bulk density of 500 gm/l, Teflon 5 differs fron Teflon 7C in not having quite as good compacting ability. Six simulant trials were made with Teflon 5; in addition to using melamine and kaolin as filler ingredients, one simulant was attempted with terephthalic acid. Exact compositions appear in Table 4. This work was discontinued when Teflon 7C was received since Teflon 5-based composites are reported not to have as high a green strength as those made using Teflon 7C (reference (8)).

The eleven remaining simulant trials were made using Teflon 7C with melamine, terephthalic acid, and vinylidene fluoride as the filler materials. These compositions are listed in Table 5. Vinylidene fluoride was included in a number of these formulations because of its thermal properties and stability at 150°C (reference (16)).

3.2.2 Simulant Properties Determination

3.2.2.1 Density: Density samples were compacted either hydraulically or isostatically and then machined into a right cylinder having nominal dimensions ranging from 1.25 to 2.5 cm for the diameter and 2.5 cm for the height. The density was calculated from the measured dimensions and weight of the sample. The densities of a number of larger charges including the thermal properties samples were measured in the same manner.

3.2.2.2 Weight Change Measurements: Weight change determinations were made for a number of simulant ingredients and compositions in both the loose powdered and compacted forms. This test consisted of subjecting a given material to various test environments and measuring the resultant change in sample weight.

For this work three test programs were chosen. The most extensively used procedure involved placing a weighed amount of material in a tared aluminum dish (6 cm diameter by 1.5 cm high) and heating in a 150.0 ± 2.5°C oven. The sample was removed and reweighed to determine the weight change for the elapsed time. All measurements were made 30 minutes after removal from the oven to allow sufficient time for the samples to cool to room temperature before weighing. Once the elevated temperature exposure was completed, selected samples were left at ambient conditions

(23 ± 3°C and 15% relative humidity) for 24 hours and then reweighed to monitor additional weight changes. Three samples were placed in a controlled high humidity environment that was obtained using a sulfuric acid solution. Approximately 100 ml of acid solution having a density of 1.142 gm/cm³ at 20°C was placed in the bottom of a desiccator, which served as the test chamber. The system was allowed to equilibrate at 20°C giving a relative humidity of 88.5% (reference (15)). Weight change measurements were made to ascertain the effect of exposure to a high humidity environment.

It is important to note that quantitative weight change guidelines were not specified for this program. Rather, this test sequence was carried out to compare simulant ingredients with HNS/Teflon 30 machinings; the machinings were tested because virgin moulding powder was not available in sufficient quantities. It was felt desirable to develop a simulant composed of ingredients whose performance did not differ significantly from that of the explosive. As a result it was possible to reject a number of potential simulant materials on this basis. It was also possible to determine the value of predrying ingredients prior to formulating simulant attempts.

3.2.2.3 Thermal Properties: The thermal diffusivity from which the thermal conductivity can be calculated and the specific heat were measured for a number of simulant trials and compared to values obtained for HNS/Teflon 30 and HNS/Teflon 7C. The thermal properties of a machined rod of Teflon bar stock were also measured and compared to literature values (reference (16)), thus giving an indication of the level of confidence to be attached to the values obtained.

The thermal diffusivity was measured using a method similar to that described in the literature (reference (17)). The sample was pressed isostatically and machined into a right cylinder having a diameter of 2.5 cm and a height of 12.7 cm with a 3.14 mm diameter hole drilled one-half the length of the cylinder. The method of mixtures (reference (18)) was used to measure the specific heat on samples having a diameter of 1.25 cm and a height of 6.35 cm. Toward the end of the program the specific heat was determined for the sample used previously to measure the thermal diffusivity.

4. Results and Discussion

The substitution of dry powdered Teflon for aqueous dispersed Teflon 30 greatly simplified the processing and improved the flow characteristics of the moulding powders for Simulant Trials #4-20. In each case the moulding powder was readily compacted either hydraulically or isostatically and the resulting billet had sufficient green strength to be machinable.

4.1 Compositions Using Teflon 5: The simulants using Teflon 5 (see Table 4) were prepared primarily to gain processing and moulding experience with dry blended powders. In addition, an effort was made to determine how varying the amounts of ingredients used in Simulant

Trial #2 affected the density of charges made from dry blended moulding powders. The results of this portion of the work are given in Table 6. Of more interest than the effect of composition on charge density is the much lower densities obtained for Trials #4 and 5. This was attributed to an apparent water weight loss that resulted from drying the moulding powder at 150°C for 72 hours prior to compaction. At this point a number of simulant ingredients and compositions in both the loose powdered and compacted forms were heated at 150°C to determine the resultant weight change. HNS/Teflon 30 machinings underwent the same test for comparison purposes.

As can be seen from the results listed in Table 7, a pellet of Trial #8 made from as-received ingredients lost nearly three times as much weight as the HNS/Teflon 30 machinings. Melamine and kaolin were found to be responsible for this; predrying these powdered materials at 150°C for 72 hours and then measuring the weight loss at 150°C resulted in a considerable decrease in weight loss. However, the weight loss determined for predried kaolin still exceeded the weight loss for HNS/Teflon 30 machinings. Upon leaving these two samples at ambient (23 ± 2°C and 15% relative humidity) for 24 hours, the kaolin gained weight and the melamine had little weight change while HNS/Teflon 30 machinings registered no measurable weight change (see Table 8). Predried melamine was then subjected to a controlled high humidity environment of 88.5% relative humidity at 20°C and this resulted in a weight gain that was not felt to be objectionable in view of the overtest (see Table 9). Based on these weight change measurements it was decided to omit kaolin from further consideration as a simulant ingredient and that melamine would have to be predried at 150°C for 72 hours before it could be incorporated in future simulant compositions.

A number of other potential filler ingredients were heated at 150°C. Of the materials tested vinylidene fluoride showed excellent temperature stability, losing less weight than predried melamine. As-received terephthalic acid was found to be marginal, while oxamide was deemed unacceptable. Both Teflon 5 and 7C were tested and found to exhibit negligible weight loss.

4.2 Compositions Using Teflon 7C: Eleven Simulant Trials were made using Teflon 7C (see Table 5) in an effort to obtain a formulation that would match the density and thermal properties of HNS/Teflon. The most logical starting point based on the weight change determinations was a composition consisting of vinylidene fluoride and Teflon. However, since there was insufficient vinylidene fluoride available, three compositions (Trials #10-12) were made using predried melamine and Teflon 7C. Trial #10 was heated to 150°C and showed excellent temperature stability losing 0.02% weight for 24 hours. However, the thermal conductivity and specific heat were much too high compared to the values obtained for HNS/Teflon (see Tables 10 and 11 for thermal properties of explosive and simulants).

Next, two compositions (Trials #13 and 14) were made using vinylidene fluoride and Teflon 7C. There was considerable improvement

in matching the thermal properties of Trial #14 with those of the explosive, but now the values were actually too low. Based on the thermal properties obtained for compositions made of melamine and vinylidene fluoride alone with Teflon 7C, four formulations (Trials #15, 17, 18 and 20) were made using vinylidene fluoride and Teflon 7C with a small amount of melamine added to increase the thermal conductivity measured for Trial #14. The thermal properties of these compositions were found to be rather strongly dependent on the amount of melamine present with Trial #20 closely matching the thermal properties of the explosive. In view of these results and the time limitations placed on this work, Trial #20 was the composition selected to simulate HNS/Teflon. A comparison of the properties of Simulant Trial #20 with both HNS/Teflon 30 machinings and HNS/Teflon 7C is given in Table 12. A list of suppliers of the ingredients in the selected simulant composition appears in Appendix A.

4.3 Compositions with Terephthalic Acid: Three inert compositions (Trials #7, 16 and 19) were made using terephthalic acid as a filler for powdered Teflon. No difficulties were experienced in processing or handling these materials. In each case the moulding powder was easily pressed either hydraulically or isostatically to yield a charge that could be easily machined. Trial #7, made using Teflon 5, was hydraulically compacted at 1757.75 kg/cm^2 (25000 psi) in a 2.5 cm (one inch) diameter steel mould to give a density of 1.60 gm/cm^3. Two other compositions were made with Teflon 7C as the binder; Simulant Trial #16 had thermal properties (see Table 11) similar to Trial #10 and 12. It was decided not to determine the thermal properties of Trial #19 since terephthalic acid offered no significant advantage over predried melamine and exhibited a greater weight loss when heated at 150°C. There was insufficient time to evaluate the effect of predrying terephthalic acid.

5. Summary

An inert simulant for the thermally stable, heat-resistant plastic-bonded explosive HNS/Teflon has been developed and tested yielding a composition which has a number of non-explosive properties that nearly match those of the explosive. The simulant consists of 66.0% vinylidene fluoride, 10.0% melamine (predried at 150°C for 72 hours) and 24.0% Teflon 7C and closely duplicates the pressed density, thermal conductivity and specific heat of the explosive while having similar processing and machining characteristics.

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*Present address U. S. Coast Guard, NASSIF Bldg., 400 7th St., S. W., Room 6211B, Washington, D. C. 20360.

Table 1

Potential Organic Filler Ingredients to be Used with Teflon 30 Emulsion

Material	Melting Point (°C)	ρ (gm/cm^3)	Solubility in 100 Parts Water	Toxicity	Cost Per Kg	Reason for Acceptance or Rejection
Ethylamine Hydrobromide	159.5	1.741	-	-	$ 78.40	Too costly.
Fumaric Acid	287	1.635	0.70 gm 17°C	-	5.80	Rather high solubility.
Gallic Acid	220(d)	1.694	1.16 gm 25°C	-	14.15	Too costly and rather high solubility.
Hexachlorobenzene	227	1.569	Insoluble	Yes	2.84	Toxic
i-Inositol	225	1.524	4.5 gm 15°C	-	48.00	Too costly and solubility too high.
Melamine	360(d)	1.573	Slightly soluble	-	2.70	Acceptable
Mesaconic Acid	202	1.466	2.7 gm 18°C	-	-	Solubility too high.
Narcotine	175	1.374	0.004 gm 20°C	-	-	Density too low.
Oxamide	419(d)	1.667	0.04 gm 7.3°C	-	38.50	Marginal - Cost too high.
Phenanthrenequinone	207	1.405	Slightly soluble	-	924.00	Cost too high and density too low.
Terephthalic Acid	248-250	1.510	Slightly soluble	-	3.75	Acceptable

Table 2

Determination of the Percent Solids
in Teflon 30 Emulsion*

Sample #		Weight % Solids
1		63.93
2		63.25
3		63.48
	Avg. =	63.55

*Du Pont Blend/Lot #2049

Table 3

Compositions of Simulant Trials Using Teflon 30

Trial #	Ingredients	Weight %
1	Melamine	62.7
	Teflon 30	37.3[1]
2	Melamine	65.6
	Kaolin[2]	22.4
	Teflon 30	12.0[1]
3	Same Composition as Trial #2 with 0.01% Dow Corning H-10 Anti-Foaming Agent	

[1]Dry Wt. %; the amount of emulsion needed to yield the desired Dry Wt. % may be calculated using

$$\frac{\text{Dry Wt \%}}{0.6355} = \text{Emulsion Wt \%}$$

[2]Kaolin NF obtained from Fisher Scientific Company.

Table 4

Compositions of Simulant Trials Using Teflon 5

Trial #	Ingredients	Weight %
4	Melamine	66.6
	Kaolin	21.4
	Teflon 5	12.0
5	Melamine	67.6
	Kaolin	20.4
	Teflon 5	12.0
6	Melamine	68.6
	Kaolin	19.4
	Teflon 5	12.0
7	Terephthalic Acid	58.3
	Kaolin	29.7
	Teflon 5	12.0
8	Melamine	52.1
	Kaolin	35.9
	Teflon 5	12.0
9	Melamine	54.5
	Kaolin	25.5
	Teflon 5	20.0

Table 5

Compositions of Simulant Trials Using Teflon 7C

Trial #	Ingredients	Weight %
10	Melamine Teflon 7C	70.0 30.0
11	Melamine Teflon 7C	62.3 37.7
12	Melamine Teflon 7C	67.0 33.0
13	Vinylidene Fluoride Teflon 7C	73.5 26.5
14	Vinylidene Fluoride Teflon 7C	73.0 27.0
15	Vinylidene Fluoride Melamine Teflon 7C	64.0 7.5 28.5
16	Terephthalic Acid Teflon 7C	68.0 32.0
17	Vinylidene Fluoride Melamine Teflon 7C	64.0 10.0 26.0
18	Vinylidene Fluoride Melamine Teflon 7C	58.0 15.0 27.0
19	Vinylidene Fluoride Terephthalic Acid Teflon 7C	64.0 7.5 28.5
20	Vinylidene Fluoride Melamine Teflon 7C	66.0 10.0 24.0

Table 6

Density Results for Melamine/Kaolin/Teflon 5 Simulant Trials

Trial #	Powder Preparation	Hydraulic Compaction Pressure kg/cm^2 (psi)	Density, gm/cm^3
2	Dried at 50°C for 24 hrs	1757.75 (25000)	1.67
4	Dried at 150°C for 72 hrs	1757.75 (25000)	1.57
5	Dried at 150°C for 72 hrs	1757.75 (25000)	1.57
6	Dried at 150°C for 72 hrs	Composition not compacted because of weight losses apparent in Trials #4 and 5.	
8	None	1406.20 (20000) 1757.75 (25000)	1.64 1.67
9	None	1757.75 (25000)	1.67-1.68*

*Four charges were made having densities ranging from 1.67 to 1.68.

Table 7

Weight Changes for Samples Heated at 150°C

Material	Physical Form	Weight Change
Simulant Trial #8	Pellet	-0.25% for 24 hrs
Simulant Trial #10	Pellet	-0.02% for 24 hrs
Melamine[1]/Teflon 5 (50/50)	Pellet	-0.13% for 67 hrs
Melamine[2]/Teflon 7C (50/50)	Pellet	-0.04% for 72 hrs
HNS/Teflon 30[3] (90/10)	Machinings	-0.09% for 21 hrs
Melamine[1]	Powder	-0.25% for 67 hrs
Melamine[2]	Powder	-0.07% for 48 hrs
Kaolin[1]	Powder	-0.22% for 24 hrs
Kaolin[2]	Powder	-0.13% for 24 hrs
Terephthalic Acid[1]	Powder	-0.12% for 24 hrs
Oxamide[1]	Powder	-2.38% for 24 hrs
Vinylidene Fluoride[1]	Powder	-0.04% for 140 hrs
Teflon 5[1]	Powder	-0.005% for 67 hrs
Teflon 7C[1]	Powder	-0.004% for 24 hrs

[1]As-received

[2]Predried at 150°C for 72 hrs

[3]ID #1378

Table 8

Weight Changes for Samples Left at Ambient[1]
After Having Been Heated at 150°C

Material	Physical Form	Weight Change
Melamine[2]	Powder	+0.003% for 24 hrs
Terephthalic Acid	Powder	+0.007% for 24 hrs
Oxamide	Powder	+0.013% for 24 hrs
Kaolin[2]	Powder	+0.013% for 24 hrs
HNS/Teflon 30[3] (90/10)	Machinings	No change

[1]Ambient conditions consisted of 23 ± 2°C and 15% relative humidity.

[2]Predried at 150°C for 24 hrs

[3]ID #1378

Table 9

Weight Changes for Samples Subjected to Controlled High Humidity Environment[1]

Material	Physical Form	Weight Change
Melamine[2]	Powder	+0.02% for 115 hrs
Melamine/Teflon 7C (50/50)	Pellet	+0.04% for 115 hrs
Simulant Trial #10	Pellet	+0.05% for 576 hrs

[1]Controlled high humidity environment was obtained using a sulfuric acid solution giving a relative humidity of 88.5% at 20°C.

[2]Predried at 150°C for 72 hrs.

Table 10

Thermal Properties of HNS/Teflon and Teflon Bar Stock

	Sample	Run	Thermal Diffusivity cm^2/sec	Density g/cm	Specific Heat cal/cm/°C	Thermal Conductivity cal/cm/sec-°C
HNS/Teflon 30 Machinings ID 1368	#1	1	$1.36x10^{-3}$	1.677	0.250	$5.702x10^{-4}$
		2	$1.33x10^{-3}$			$5.576x10^{-4}$
	#2	1	$1.43x10^{-3}$	1.674	0.250	$5.985x10^{-4}$
		2	$1.42x10^{-3}$			$5.943x10^{-4}$
	Average		$1.39x10^{-3}$	1.676	0.250	$5.802x10^{-4}$
HNS/Teflon 7C		1	$1.34x10^{-3}$	1.689	0.249	$5.636x10^{-4}$
Teflon Machined Rod	#1	1	$0.92x10^{-3}$	2.207	0.259	$5.259x10^{-4}$
		2	$0.93x10^{-3}$			$5.316x10^{-4}$
	#2	1	$0.95x10^{-3}$	2.207	0.259	$5.430x10^{-4}$
		2	$0.92x10^{-3}$			$5.259x10^{-4}$
	#3	1	$0.96x10^{-3}$	2.207	0.259	$5.487x10^{-4}$
		2	$0.98x10^{-3}$			$5.602x10^{-4}$
	Average		$0.94x10^{-3}$	2.207	0.259	$5.392x10^{-4}$
Teflon*		-	--	2.14-2.20	0.250	$6.0x10^{-4}$

*Reference (16).

Table 11

Thermal Properties of Simulant Trials

	Run	Thermal Diffusivity cm^2/sec	Density g/cm^3	Specific Heat $cal/cm/^\circ C$	Thermal Conductivity $cal/cm/sec-^\circ C$
Simulant #10	1	3.92×10^{-3}	1.652	0.300	19.428×10^{-4}
	2	3.78×10^{-3}			18.734×10^{-4}
	1	4.10×10^{-3}	1.653	0.300	20.332×10^{-4}
	2	3.85×10^{-3}			19.092×10^{-4}
	Average	3.91×10^{-3}	1.653	0.300	19.397×10^{-4}
Simulant #12	1	3.88×10^{-3}	1.651	0.302	19.346×10^{-4}
Simulant #14	1	0.882×10^{-3}	1.684	0.261	3.877×10^{-4}
Simulant #15	1	1.03×10^{-3}	1.684	0.264	4.579×10^{-4}
	2	1.06×10^{-2}			4.713×10^{-4}
	Average	1.05×10^{-3}			4.668×10^{-4}
Simulant #16	1	4.94×10^{-3}*	1.686	0.270	22.488×10^{-4}
	2	4.22×10^{-3}			19.210×10^{-4}
	Average	4.22×10^{-3}			19.210×10^{-4}
Simulant #17	1	1.32×10^{-3}	1.718	0.239	5.420×10^{-4}
	2	1.26×10^{-3}			5.174×10^{-4}
	Average	1.29×10^{-3}			5.297×10^{-4}
Simulant #18	1	1.33×10^{-3}	1.728	0.296	6.803×10^{-4}
	2	1.33×10^{-3}			6.803×10^{-4}
	Average	1.33×10^{-3}			6.803×10^{-4}
Simulant #19	Not Determined				
Simulant #20	1	1.22×10^{-3}	1.708	0.278	5.793×10^{-4}

*Value not used. Chart speed considered too slow to give accurate result.

Table 12

Comparison of HNS/Teflon and Simulant Properties

Property	HNS/Teflon 30 Machinings	HNS/Teflon 7C	Simulant
Composition Type	Pressed	Pressed	Pressed
Processing Procedure	Slurried*	Dry Blended	Dry Blended
Machinability	Excellent	Excellent	Excellent
Compaction Pressure, kg/cm^2 (psi)	1757.75 (25000)	1757.75 (25000)	1757.75 (25000)
Density, gm/cm^3	1.676	1.689	1.708
Specific Heat, cal/gm/°C	0.250	0.249	0.278
Thermal Conductivity, cal/cm/sec-°C	5.802×10^{-4}	5.636×10^{-4}	5.793×10^{-4}

*This material was made by pressing machinings that were left over from the ALSEP program. The original moulding powder was obtained by slurrying HNS with aqueous dispersed Teflon 30.

APPENDIX A

List of Suppliers of Simulant Ingredients

Vinylidene Fluoride (Resin, Kynar RC-2525 Moulding Powder, Grade 301)	Pennwalt Corporation Three Parkway Philadelphia, Pa. 19102
Melamine (Stock No. 1540)	Eastman Kodak Company Eastman Organic Chemicals 343 State St. Rochester, N. Y. 14650
Teflon 7C	E. I. du Pont de Nemours and Company, Inc. 170 Mount Airy Road Basking Ridge, N. J. 07920